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Combined economic and emission dispatch solution using Flower Pollination Algorithm

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ABSTRACT

Economic Load Dispatch (ELD) is the process of allocating the required load between the available generation units such that the cost of operation is minimized. The ELD problem is formulated as a nonlinear constrained optimization problem with both equality and inequality constraints. The dual-objective Combined Economic Emission Dispatch (CEED) problem is considering the environmental impacts that accumulated from emission of gaseous pollutants of fossil-fueled power plants. In this paper, an implementation of Flower Pollination Algorithm (FPA) to solve ELD and CEED problems in power systems is discussed. A comparison of the simulated results using the proposed FPA is carried out to confirm its effectiveness against other swarm intelligent algorithms for six various power systems. The superiority of the proposed FPA compared with other algorithms is demonstrated even for large scale power system considering valve point loading effect.

Introduction

Economic Dispatch (ED) problem has become a crucial task in the operation and planning of power system [1]. It is very complex to solve because of a nonlinear objective function and a large number of constraints. ED in power system deals with the determination of optimum generation schedule of available generators so that the total cost of generation is minimized within the system constraints [2,3]. Well known long-established techniques such as gradient method [4], lambda iteration method [5,6], linear programming [7], quadratic programming [8], lagrangian multiplier method [9] and classical technique based on co-ordination equations [10] are applied to solve ELD problems. These conventional methods cannot perform satisfactory for solving such problems as they are sensitive to initial estimates and converge into local optimal solution in addition to their computational complexity.

During the last decades many researches and techniques had dealt with ELD problems. Fuzzy Logic Control (FLC) has attracted the attention in control applications. In contrast with the conventional techniques, FLC formulates the control action in terms of linguistic rules drawn from the behavior of a human operator rather than in terms of an algorithm synthesized from a model of the system [11–14]. However, it requests more fine tuning and simulation before operational. Another technique likes Artificial Neural Network (ANN) has its own advantages and disadvantages. The characteristics of the system is enhanced by ANN, but the main problem of this technique is the long training time, the selecting number of layers and the number of neurons in each layer [15–18].

An alternative approach is to employ Evolutionary Algorithm (EA) techniques. Due to its ability to treat nonlinear objective functions, EA is believed to be very effective to deal with ELD problem. Among the EA techniques, Genetic Algorithm (GA) is introduced in [19,20], but it requires a very long run time depending on the size of the system under study. Also, it gives rise to repeat revisiting of the same suboptimal solutions. Simulated Annealing (SA) is illustrated in [21,22], but this technique might fail by getting trapped in one of the local optimal. Evolutionary Programming (EP) is discussed in [23], but it has a slow convergence rate for large problem. Improved Tabu Search (TS) is introduced in [24], but the efficiency of this algorithm is reduced by the use of highly epistatic objective functions and the large number of parameters to be optimized. Also, it is time consuming method. Ant swarm optimization is presented in [25], but its theoretical analysis is difficult and probability distribution changes by iteration. Particle Swarm Optimization (PSO) is discussed in [26–29], but it pains from the partial optimism. Moreover, the algorithm cannot work out the problems of scattering and optimization. Gravitational Search Algorithm (GSA) in illustrated in [30]. However, this algorithm appears to

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Nomenclature

F_t	the total fuel cost of generation in $
$F_i(P_i)$	the fuel cost function of ith generator in $
$\gamma_i, \beta_i, \alpha_i$	the cost coefficients of ith generator in $/MW^2, $/MW and $ respectively
P_i	the real power generation of ith generator in MW
d	the number of generators connected in the network
P_D	the total load of the system in MW
P_L	the transmission losses of the system in MW
P_i, P_j	the real power injections at ith and jth buses respectively
B_{ij}, B_{0i}, B_{00}	the loss-coefficients of transmission loss formula
$P_i^{\min}, P_i^{\max}$	the minimum and maximum values of real power allowed at generator i
e_i, f_i	the coefficients of ith generator due to valve point effect in $ and MW^{-1} respectively
F	the optimal cost of total generation and emission
$F_i(P_i), E_i(P_i)$	the total fuel cost and total emission of generators respectively
a, b, c	the emission coefficients of generators in kg/MW^2, kg/MW and kg respectively
η_i, δ_i	the emission coefficients of ith generator in Ton and MW^{-1} respectively
h	the price penalty factor value in $/kg
x_i^t	the pollen i
g_*	the current best solution found at the current generation
γ	the scaling factor controlling the step size
$\Gamma(\lambda)$	the standard gamma function
p	switch probability

List of abbreviations

ELD	Economic Load Dispatch
CEED	Combined Economic Emission Dispatch
FPA	Flower Pollination Algorithm
ED	Economic Dispatch
FLC	Fuzzy Logic Control
ANN	Artificial Neural Network
EA	Evolutionary Algorithm
GA	Genetic Algorithm
SA	Simulated Annealing
EP	Evolutionary Programming
TS	Tabu Search
PSO	Particle Swarm Optimization
GSA	Gravitational Search Algorithm
ABC	Artificial Bee Colony
QP	Quadratic Programming
DE	Differential Evolution
CS	Cuckoo Search
FA	Firefly Algorithm
SFL	Shuffled Frog Leaping algorithm
BFO	Bacteria Foraging Optimization
PPSO	Personal best-oriented PSO
APPSO	Adaptive Personal-best oriented PSO
MPSO	Modified Particle Swarm Optimization
ARCGA	Adaptive Real Coded GA
TSAGA	Taguchi Self-Adaptive real-coded Genetic Algorithm
CCPSO	PSO with both Chaotic sequences and Crossover operation
CDE_SQP	combining of chaotic DE and quadratic programming
EDA/DE	estimation of distribution and differential evolution cooperation
SOMA	Self-Organizing Migrating Algorithm
CSOMA	Cultural Self-Organizing Migrating Algorithm
DE/BBO	combination of differential evolution and biogeography-based optimization
DHS	Differential Harmony Search
BBO	Biogeography Based Optimization
PSO–SQP	integrating PSO with the Sequential Quadratic Programming
GA–PS–SQP	hybrid algorithm consisting of GA, Pattern Search (PS) and SQP
CPSO	Chaotic Particle Swarm Optimization
CPSO–SQP	Hybrid algorithm consisting of CPSO and SQP
NPSO_LRS	New PSO with Local Random Search
CDEMD	Cultural DE based on measure of population's diversity
HMAPSO	Hybrid Multi Agent based PSO
FAPSO-NM	Fuzzy Adaptive PSO algorithm with Nelder–Mead
MODE	Multi-Objective Differential Evolution
NSGA-II	Non dominated Sorting Genetic Algorithm-II
PDE	Pareto Differential Evolution
SPEA-2	Strength Pareto Evolutionary Algorithm 2
ABC_PSO	ABC and PSO
EMOCA	Enhanced Multi-Objective Cultural Algorithm
MABC/D/Cat	Modified Artificial Bee Colony with Disruptive Cat map
MABC/D/Log	Modified Artificial Bee Colony with Disruptive Logistic map
CPU	Computational time
NA	Not Available
PV	Photovoltaic

be effective for solving ELD problem, it has poor performance at the later search stage due to the lack of agents' diversity in GSA. Artificial Bee Colony (ABC) is developed in [31] to solve the complex non-linear optimization problem, but it is slow to converge and the processes of the exploration and exploitation contradict with each other, so the two abilities should be well balanced for achieving good optimization performance. On the other hand, FPA has only one key parameter p (switch probability) which makes the algorithm easier to implement and faster to reach optimum solution. Moreover, this transferring switch between local and global pollination can guarantee escaping from local minimum solution. Thus, FPA is proposed in this paper to overcome the previous drawbacks.

In this paper, a new approach for solving ELD and CEED problems using FPA methodology considering the power limits of the generator. The purpose of CEED is to minimize both the operating fuel cost and emission level simultaneously while satisfying load demand and operational constraints. This multi-objective CEED problem is converted into a single objective function using a modified price penalty factor approach. FPA is investigated to determine the optimal loading of generators in power systems. Simulations results for small and large scale power systems with considering valve loading effect are implemented to indicate the robustness of FPA.

The remainder of this paper is organized as follows: Section 'Problem formulation' provides a brief description and mathematical formulation of ELD and CEED problems. In Section 'Overview of Flower Pollination Algorithm', the concept of FPA is discussed. Section 'Results and discussion' shows the result on three, six, ten and forty unit thermal test systems. Finally, the conclusion and future work of research are outlined in Section 'Conclusions'.